Identifying Abandoned Mineshafts near Railroads

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Scotland

Sponsors:

- Argentinian Government
- Carillion plc
- Civil Tech NDT Ltd
- EPSRC
- GT Railway Maintenance Ltd/Carillion Rail
- Highways Agency, London, UK
- Holequest Ltd
- Network Rail Infrastructure Ltd
- TRL Ltd
- Industry……!
- University of Edinburgh

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University of Edinburgh: NDT Standards

- **Highways Agency (HA) Advisory Notes (2004): BA65**

  NDT of Masonry Arch & Concrete Bridges

  (i) Radar Testing of masonry bridges
  (ii) Sonic transmission testing of masonry bridges
  (iii) Conductivity testing of masonry bridges
  (iv) Ultrasonic tomography of p-t concrete bridge bean
  (v) Impact-echo testing of p-t concrete bridge beams

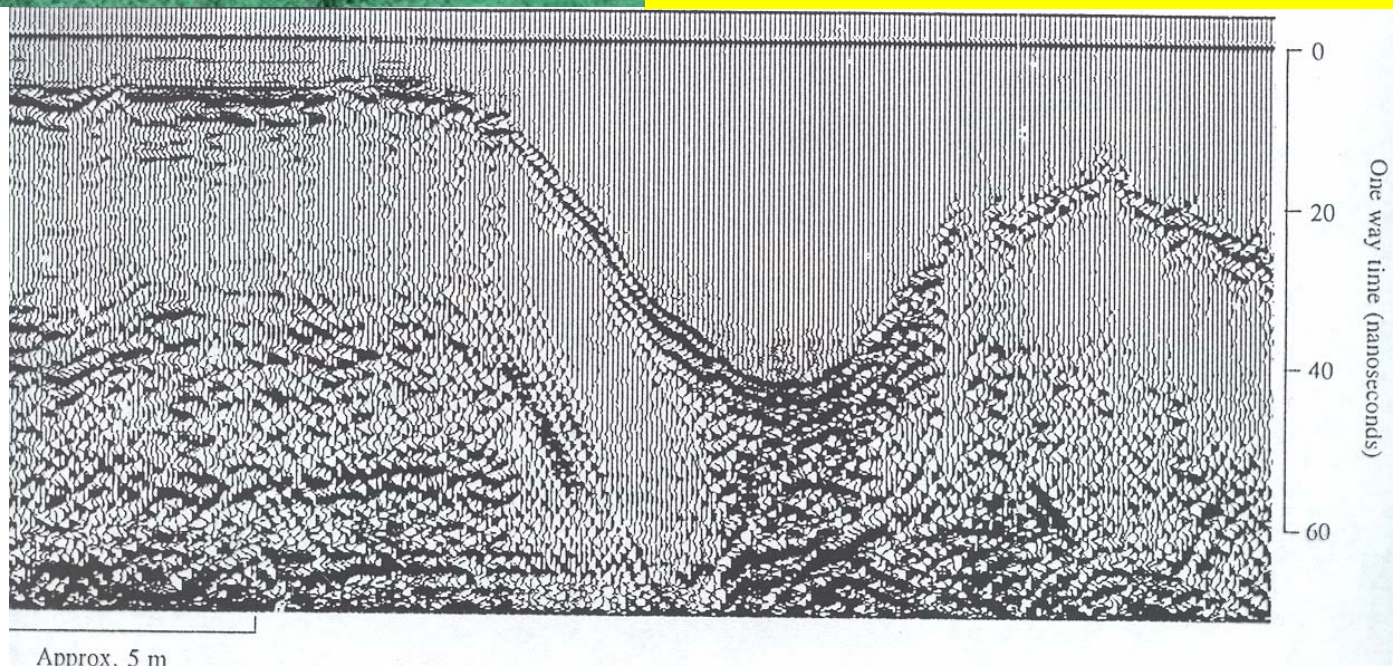
- **ACI 228-2R-98 NDT of Concrete (update: 2003)**

  2.3 Impact echo
  2.7 Infra-red thermography (IR)
  2.8 Radar (GPR)
  2.9 Acoustic Emission (AE)
  2.10 Ultrasonic Tomography

4. Bridge Scour- GPR

Float Viaduct: Carstairs

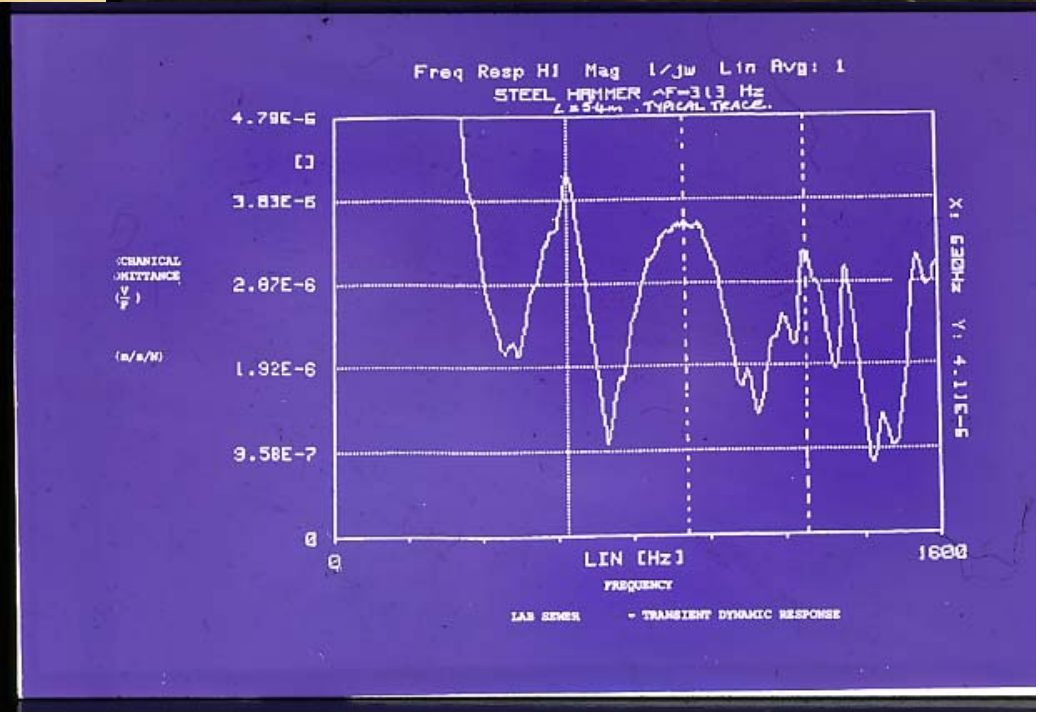
GPR Survey



NDT Topics Investigated

1. **Theory** behind research; output: 50 jnl + 120 conf papers + 13 PhDs + 2 MSc
2. **Railway Track** - GPR + Infra-Red Thermography
3. **Masonry Arch Bridges** – tomography

5. Sewers - FRF


Freq Resp H1 Mag 1/jw Lin Avg: 1
STEEL HAMMER AF=313 Hz
L=54m . TYPICAL TRACE.
4.79E-6
[]
3.83E-6
2.87E-6
1.92E-6
9.58E-7
0
0
LIN [Hz]
1600
FREQUENCY
LAB SEWER - TRANSIENT DYNAMIC RESPONSE

6. Concrete

228298

Member Price ~~$27.00~~
Convention Price $24.00

ACI 228.2R-98

Nondestructive Test Methods for Evaluation of Concrete in Structures

Reported by ACI Committee 228

american concrete institute
P.O. BOX 9094
FARMINGTON HILLS, MICHIGAN 48333-9094

- **Funding:** **Network Rail Infrastructure Ltd**

- **We need:**

1. **YOUR FEEDBACK on our ideas**
2. **+ Case Studies on identifying Abandoned Mineshafts**

Please…!!

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Overview

- Introduction
- Geophysical methods
- Microgravity
- Magnetic & Electromagnetic methods
- Ground Penetrating Radar
- Resistivity Methods
- Seismic Methods:
    - Reflection
    - Refraction
    - Tomography
- Future
- Conclusions

Introduction

The problem

- Abandoned mineshaft = hazard to railroads.
- Drilling: expensive, intrusive & many B.H.s to to detect shaft.
- Geophysical methods tried - none produced any satisfactory results

The reasons for failure??

- Contractor executed the survey improperly ??
- Presence of railroad limits the performance ??
- Chosen geophysical method - not suitable for the target ??

Geophysical methods

(1) Geophysical methods - routinely used to detect subsurface voids.

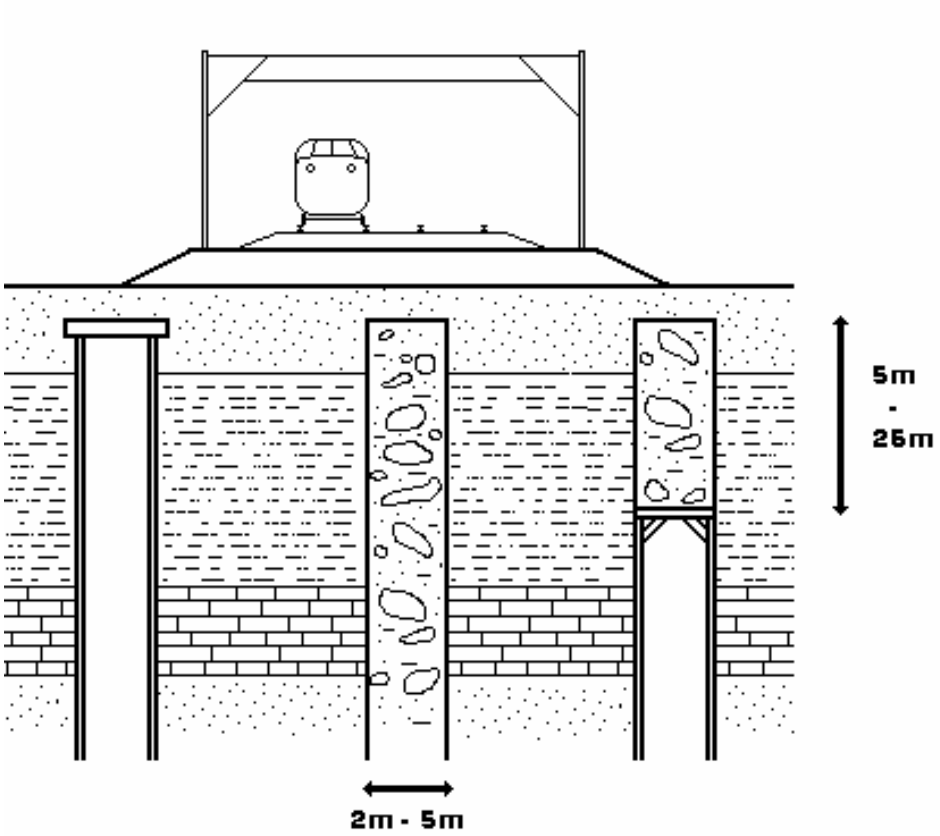
(2) Delineation of mineshafts is not straightforward:

- **Shaft extends vertical**
- **Geophysical survey is conducted on a horizontal plane at surface.**
- **Small size of the shaft in relation to the survey area.**
- **Physical contrasts between host and shaft can be low.**

Mineshaft

Description of the mineshaft

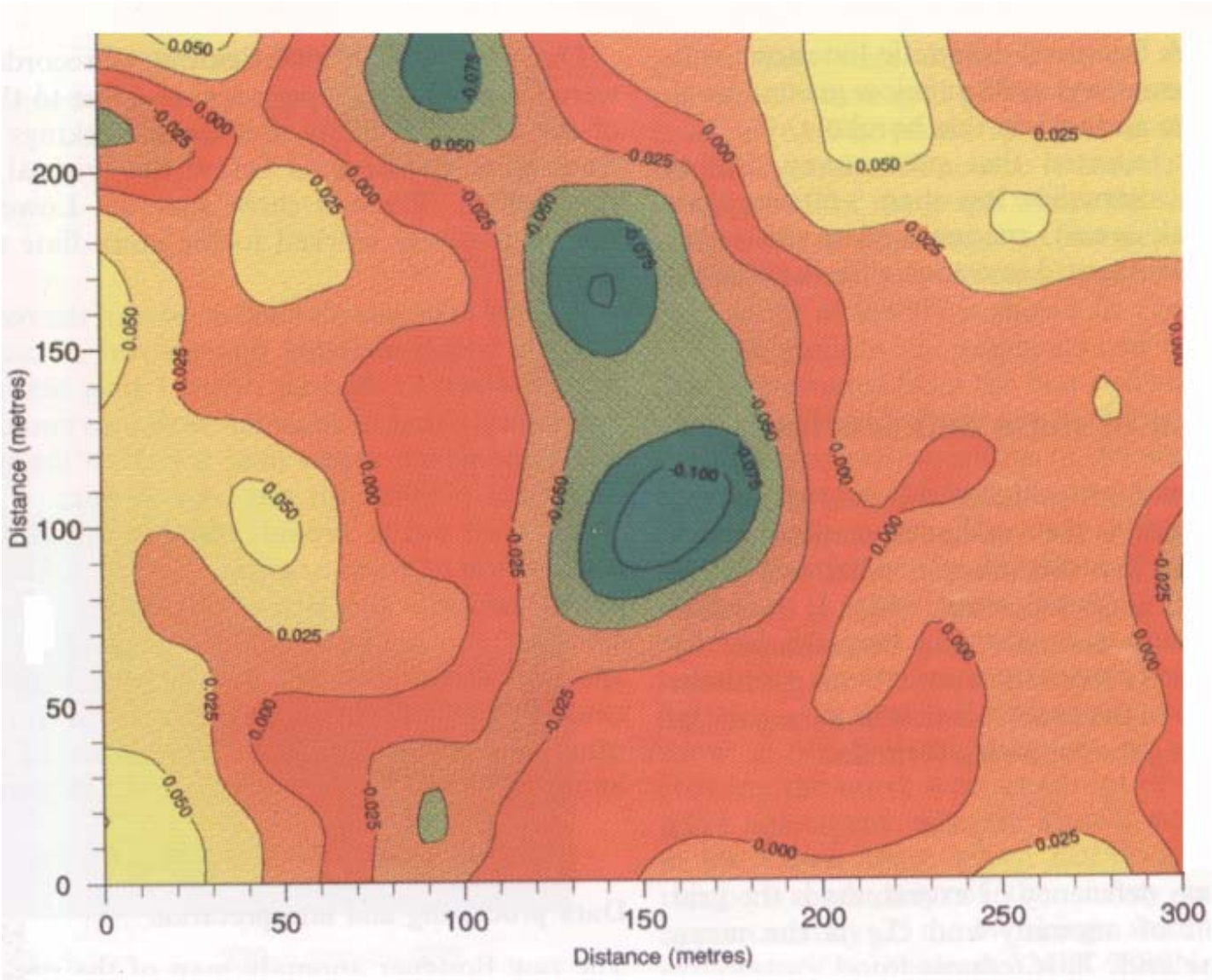
- Capped, completely filled or partially filled
- Size: 2m to 5m
- Platform depth: 5m to 25m
- Lining material: brick, wood etc.
- Lining is often partially removed
- Backfilling: rubble, timber, soil, etc.
- Platform made of wood, iron or masonry



Microgravity

Object: Measuring density contrast in subsurface

Measured parameter: Variation in the gravitational field



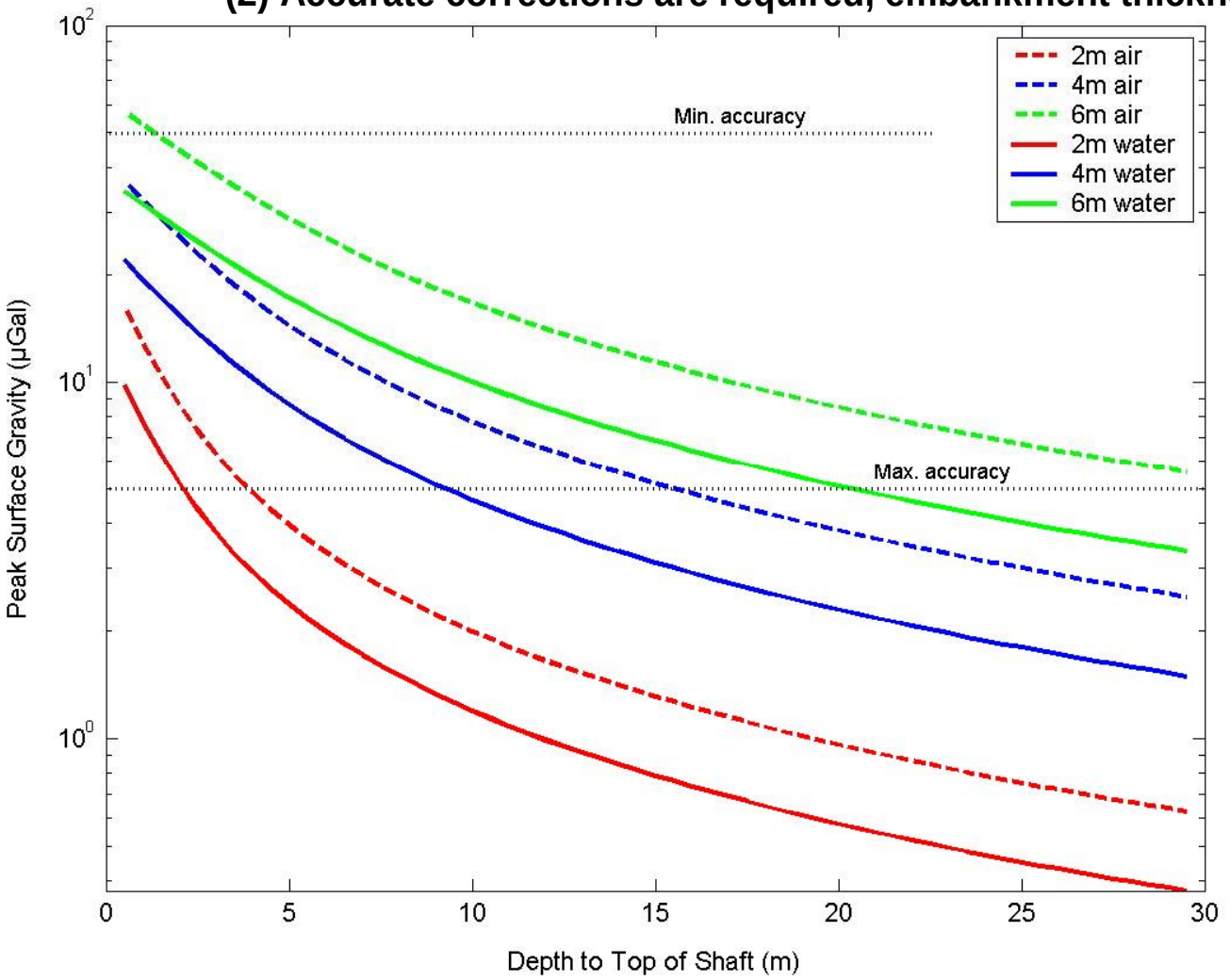
Microgravity

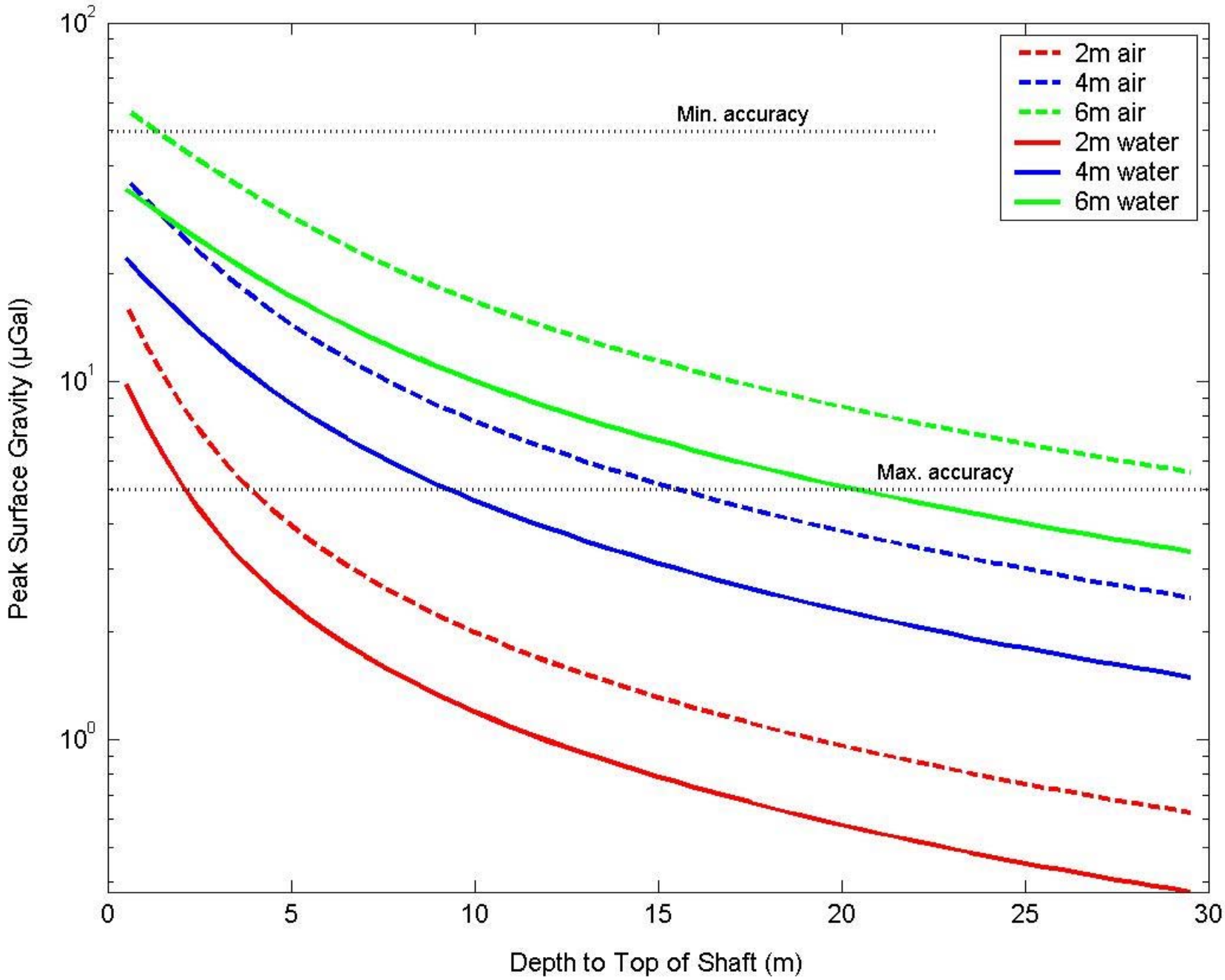
Max depth: Depends dimension of the shaft, density contrast & accuracy of measurements

Resolution: Horizontal resolution depends on station spacing

Limitations: (1) Ambiguous interpretation

(2) Accurate corrections are required, embankment thickness - often unknown




2m air
4m air
6m air
2m water
4m water
6m water
Min. accuracy
Max. accuracy
Peak Surface Gravity (µGal)
Depth to Top of Shaft (m)
10^2
10^1
10^0
0
5
10
15
20
25
30

Electromagnetic + magnetic methods

Objective: Detection of metals or resistivity contrasts

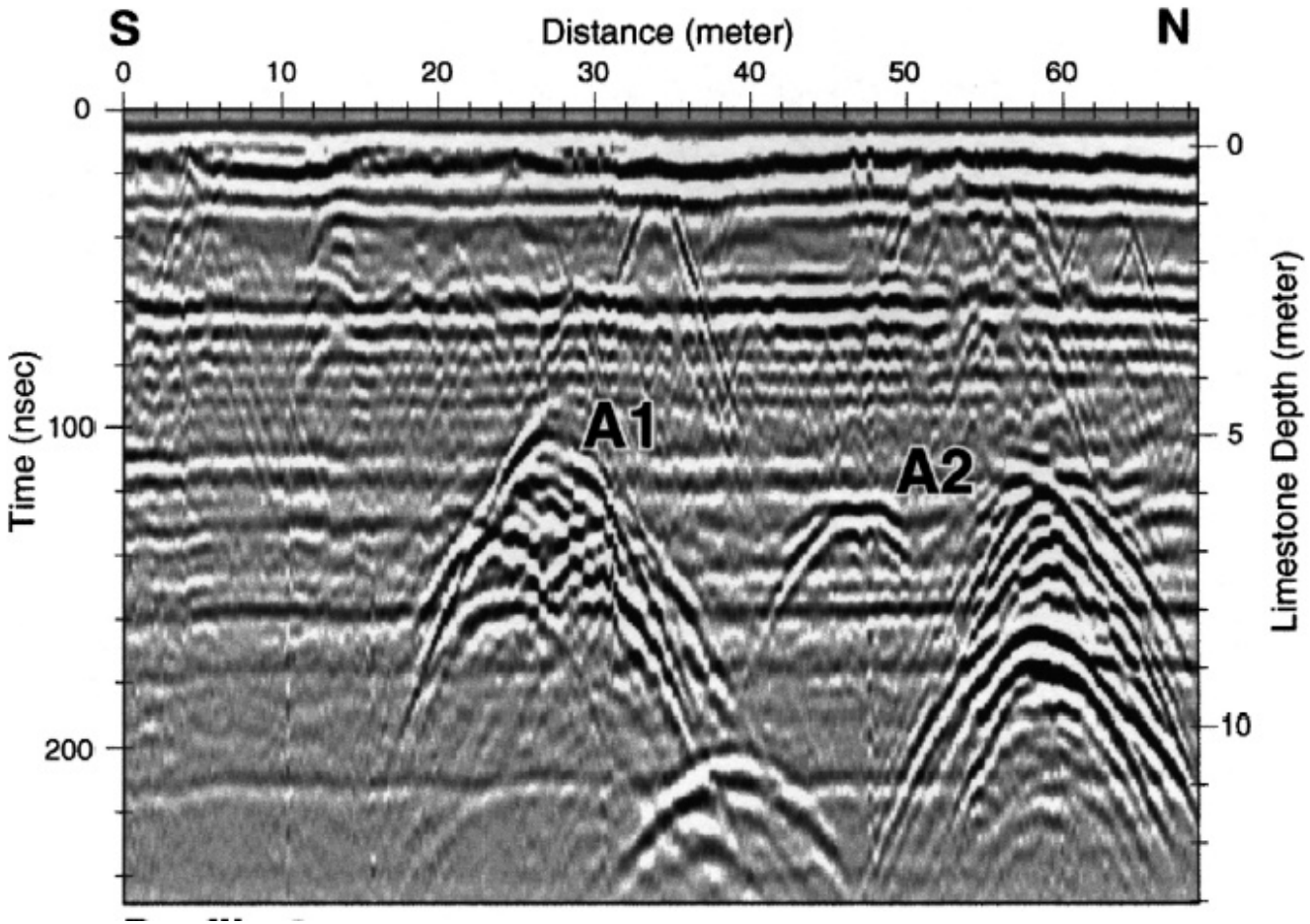
Measured parameter: Magnetic field or electromagnetic response to a primair transmitted EM field

Limitations: Both methods attenuated by presence of metal, e.g. rails…!!

Ground Penetrating Radar -GPR

Objective: Measuring changes in dielectric permitivity

Measured parameter: Reflected EM waves



Ground penetrating radar

Max depth: Depends on centre frequency - & conductivity dependent (0.1 m to 30 m)

Resolution: Horizontal resolution depends on station spacing

Limitations: (1) Lack of penetration depth in high conductivity soils e.g. clays

(2) Shielding is necessary

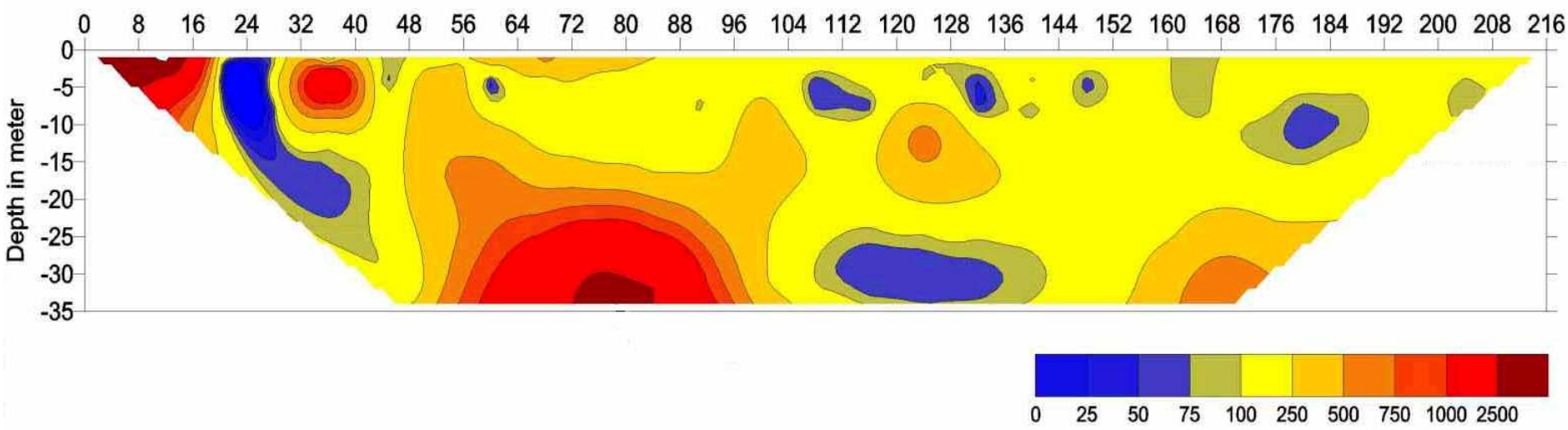
(3) Survey limited to measurements between rails AND between ties

Conductivity (mS/m)	Material	Range (m)
0.5	Limestone	30
1	Gravel	15
2	Sand	7.5
4	Sandstone	4
8	Coal	2.5
16	Clay	1.5
32	Shales	1

Resistivity methods

Objective: **Resistivity profile of the subsurface**

Measured parameter: **Apparent resistivity/voltage**



Resistivity methods

Max depth: 2 to 3 x dipole length (dipole – dipole configuration)

Resolution: Decreasing with increasing station and dipole spacing

Limitations: (1) Requires resistivity contrast between the filling and surrounding material

(2) Direct measurements on or below the embankment - difficult

	Mineshaft	h/R = 1	h/R = 1.5	h/R = 2	h/R = 2.5
Clay	Air	+	+	+	+
	Water	+	+	-	-
Sand	Air	+	+	□	-
	Water	+	+	+	+
Limestone	Air	+	+	-	-
	Water	+	+	+	-
Granite	Air	+	+	-	-
	Water	+	+	□	□
Basalt	Air	+	+	-	-
	Water	+	+	□	□

\+ Anomaly effect > 1.1

\- Anomaly effect < 0.9

□ Anomaly effect < 0.9 > 1.1

Seismic methods

Objective: Delineation of mineshaft by seismic waves

Measured parameter: 1) Travel time & amplitude of reflected waves

2) Travel time of refracted waves

3) Velocity variation

Seismic methods: reflection

Max depth: From 2 m to 300 m and further

$$Optimum \quad frequency \quad \approx \quad \frac{velocity^2 \cdot traveltime}{2 \cdot diameter^2}$$

Resolution: Horizontal resolution depends on:

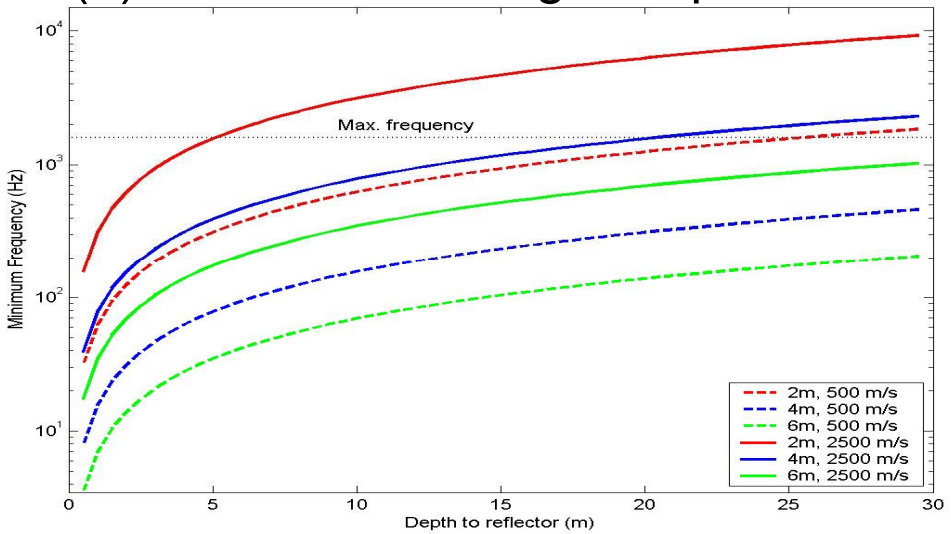
(1) frequency of wave

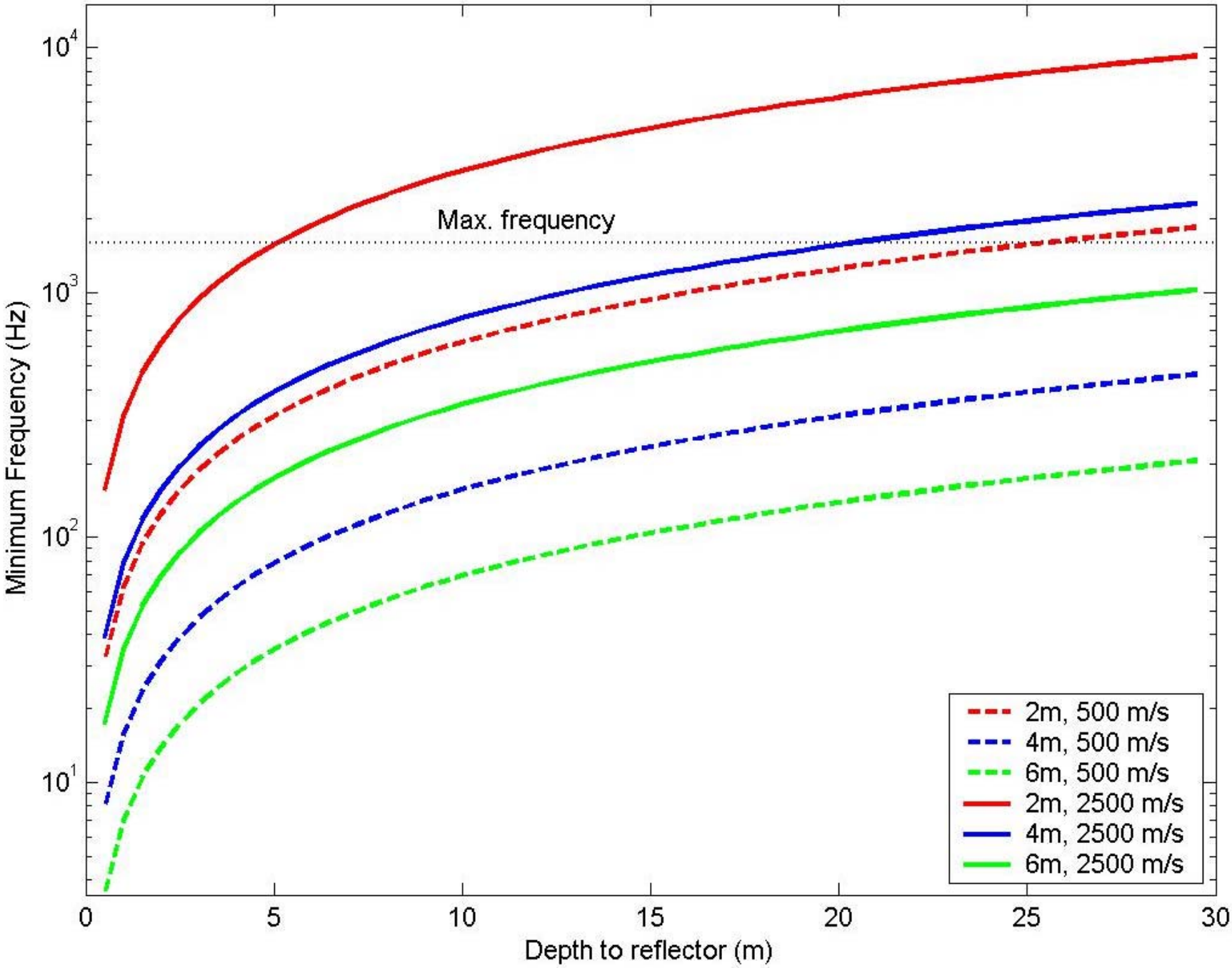
(2) velocity through the overburden

(3) dia. & depth of mineshaft:

Limitations: (1) High frequencies required for small targets

(2) Attenuation of high frequencies at ballast layer




Minimum Frequency (Hz)
10^4
10^3
10^2
10^1
Max. frequency
0
5
10
15
20
25
30
Depth to reflector (m)
2m, 500 m/s
4m, 500 m/s
6m, 500 m/s
2m, 2500 m/s
4m, 2500 m/s
6m, 2500 m/s

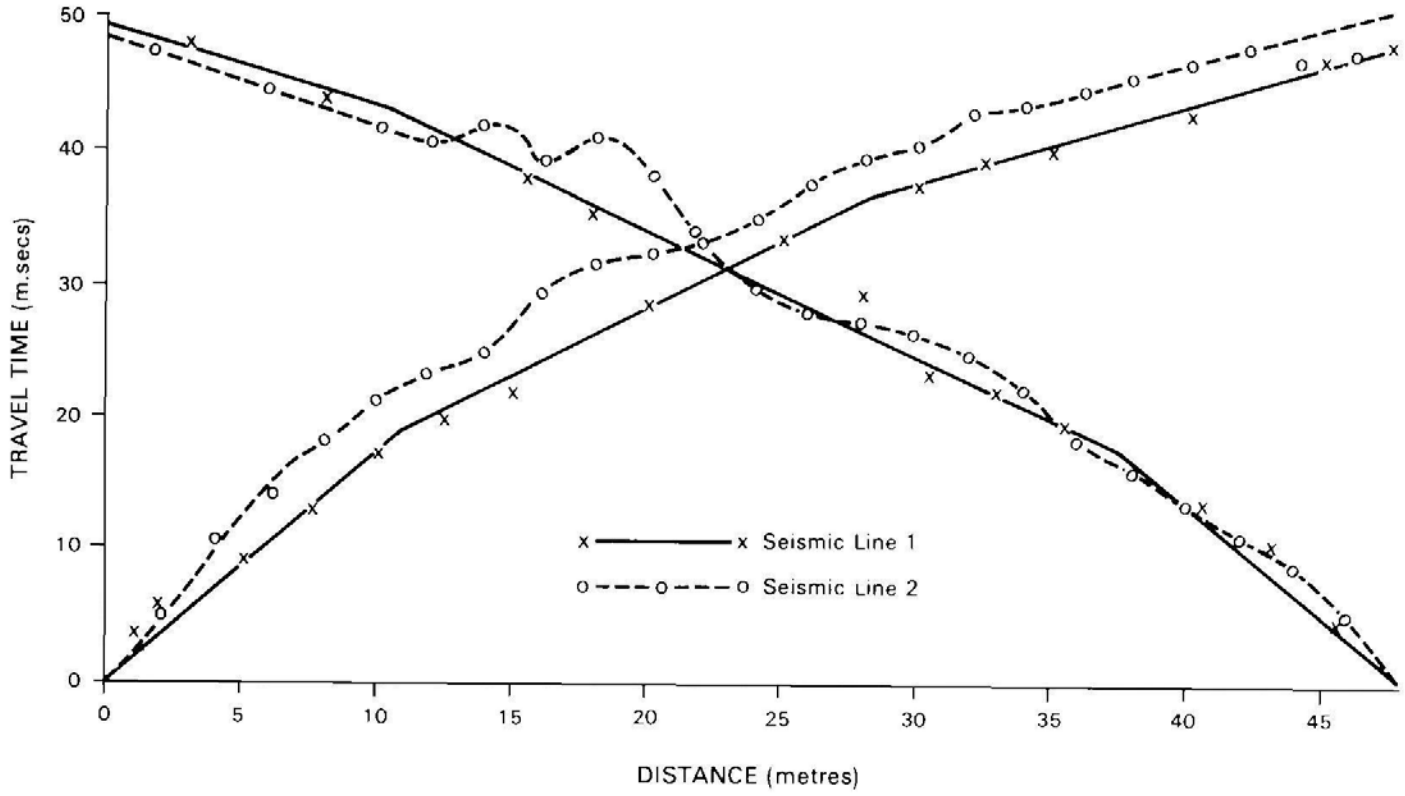
Seismic methods: refraction

Max depth: **From 5 m to … 300m and further….**

Resolution: **Travel time lag depends on wavelength in relation to the size of shaft.**

Limitations: **(1) High frequencies required for small targets**

(2) Attenuation of high frequencies at ballast layer

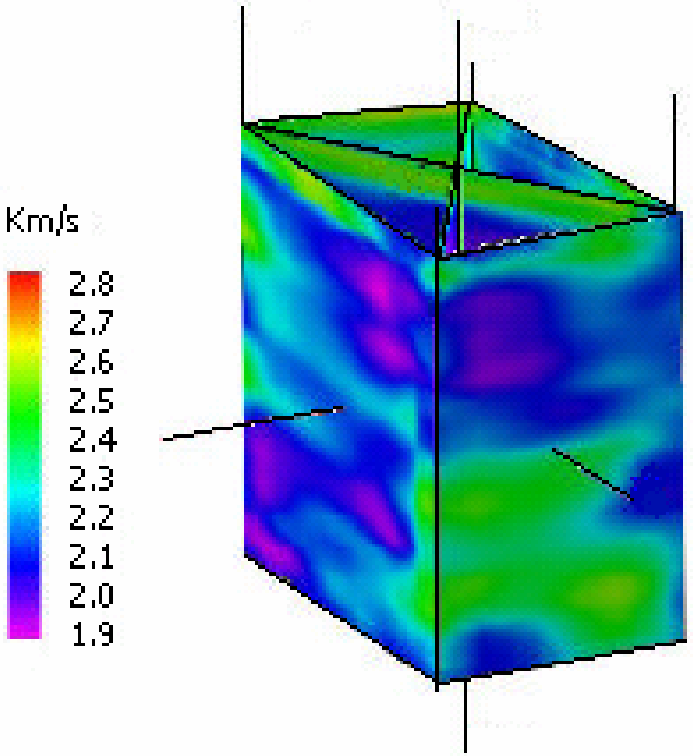


Seismic methods: tomography

Max depth: Only limited by depth of borehole

Resolution: Minimum size of anomaly = wavelength

Limitations: (1) Requires boreholes: intrusive & expensive
(2) Measurements limited to area between boreholes.



Future

Development of new geophysical instruments, measurement methods & interpretation software are on-going.

Geophysical techniques that have potential include:

- **Diffraction/scattering of seismic waves**
- **Refraction tomography**
- **Thermal techniques**
- **Downhole radio imaging method**
- **????? Ideas please….!!**

Future Experiments in Edinburgh

Geophysical Experiments on our test track:

Conclusions

(1) Difficult to delineate a concealed mineshaft.

(2) Especially if partially or completely filled shaft.

(3) Presence of the rails & railroad embankment imposes serious limitations on methods

(4) Metals interfere with EM and magnetic methods

(5) Ballast material limits the performance of resistivity methods & seismic methods

(6) Corrections for embankment are not accurate for the microgravity

(7) Methods that don't involve measuring on the track are particularly interesting: tomography and refraction.

Thank You!

We need:

1. **YOUR FEEDBACK on our ideas**
2. **+ Case Studies of Identifying Mineshafts**

Please…!!

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